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Seasonal Average Length Trends at Monterey of the California Sardine (*Sardina caerulea*)

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Terminal, California

By
CARROLL B. ANDREWS

Contribution No. 70 from the California State Fisheries Laboratory

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SEASONAL AVERAGE LENGTH TRENDS AT MONTEREY OF THE CALIFORNIA SARDINE (*Sardina caerulea*)[1]

By Carroll B. Andrews

Any person associated with the sardine industry is well acquainted with the progressive increase in length of the sardines taken throughout a fishing season. Small and mixed sizes are taken in the summer months, while the winter fishery consists chiefly of large fish. Such a seasonal variation is not common or, at least, has not been reported for any other important commercial fish in California. It is of primary interest, then, to define this trend in the sizes of sardines throughout each season and to compare the trends from year to year.

During the past eight years, 1919–1927, the California State Fisheries Laboratory has made a detailed study of the sardine catch at Monterey. These records supply data for lengths of a representative sample of the catch for the entire fishing season and thus reflect changes in size from day to day, week to week and month to month.

From 1919 to 1923 samples were taken daily, but as a result of Sette's analysis of the sampling method,[2] showing the adequacy of semiweekly samples, beginning with the 1923–1924 season the catch was sampled semiweekly. The data of the first four seasons, therefore, are obtained from daily samples while the last four seasons are from semiweekly samples. Scofield[3] described the method of sampling followed during the first four years, 1919–1923. During that period of time five samples of twenty fish were taken from five boats, totaling 100 fish per day. From 1923 to 1927 five samples of forty fish were taken from five separate boats twice a week. The fish were measured and sexed, the sum of the body lengths of the fish compiled, and the daily average length determined by dividing this total by the entire number of fish. The averages for each sample day for the 1923–1924 season are plotted in figure 1, and show fluctuations between the daily averages throughout the season. Due to the fact that daily variations in length tend to obscure the seasonal variations, use was made of a statistical means for obtaining a seasonal trend. This was accomplished by smoothing the daily averages by a moving average of 29 calendar days. The smoothed curve of the semiweekly averages is given as the heavy solid line of figure 1, and shows the effect the smoothing process has on the original data.

The trends of the average lengths for the first four of the eight seasons observed are shown in figure 2.[4] The trends of the first two

[1] Contribution No. 70 from the California State Fisheries Laboratory, March, 1928. The author wishes to acknowledge the assistance of Miss Annie Gillespie in smoothing and graphing the length data, and to express his appreciation for aid and direction given by Miss Frances N. Clark and Mr. W. L. Scofield.

[2] Sette, Oscar Elton. Sampling the California Sardine: A Study of the Adequacy of Various Systems at Monterey. California Fish and Game Commission, Fish Bulletin No. 11. 1926.

[3] Scofield, W. L. The Sardine at Monterey: Dominant Size-classes and their Progression, 1919–1923. California Fish and Game Commission, Fish Bulletin No. 11, p. 196. 1926.

[4] Reprinted through courtesy of W. L. Scofield from "The Sardine at Monterey: Dominant Size-classes and their Progression, 1919–1923." California Fish and Game Commission, Fish Bulletin No. 11, p. 200. 1926.

seasons cover only the latter portion of the actual fishing period due to unavoidable delays in beginning the sampling. Samples taken throughout the two entire seasons indicate the average lengths of the fish taken during the summer and fall months. The transition from November to the end of January is decidedly more marked for the 1921–1922 and 1922–1923 seasons than for the two preceding ones. This is indicated

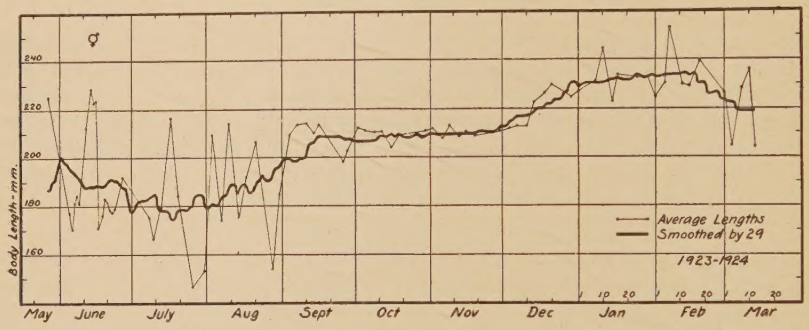

FIG. 1. A graph to show the effect of smoothing upon the average length data, 1923–1924 season.

by the relatively greater change in the length of the fish between November and February for the last two seasons than for the first two periods.

The heavy solid line in the lower graph of figure 2 represents the average of the four seasonal trends given in the upper graph. This demonstrates more concretely the fluctuations in size throughout a season. The July and early August fish are the smallest, averaging only 190 mm. in length. The following three months display no prom-

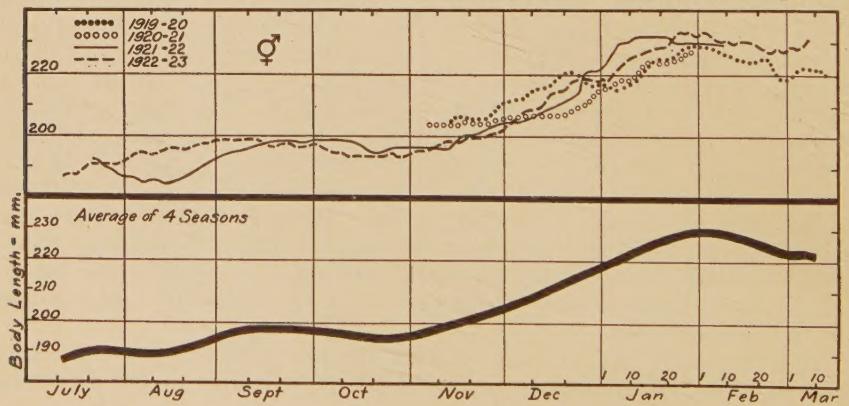

FIG. 2. Showing (above) the trend of daily average lengths of fish for four fishing seasons, and (below) the average of the four trends.

inent features but lead to an unmistakable transition period during November, December and January. The average lengths reach the highest point of the season in late January or early February and then decline as the close of the fishing season is approached.

The four seasonal trends of 1923–1924 to 1926–1927 given in the upper graph of figure 3, show a wider variation during the summer

months than at any other period. The 1923–1924 season is abnormally low, having a minimum average length of 174 mm. in mid-July. Figure 1 shows the wide deviation of the semiweekly average lengths with the majority of the averages falling below 185 mm. for June, July and August. For the remainder of the season this trend maintains a close relationship to the trends of the other three seasons. The trends

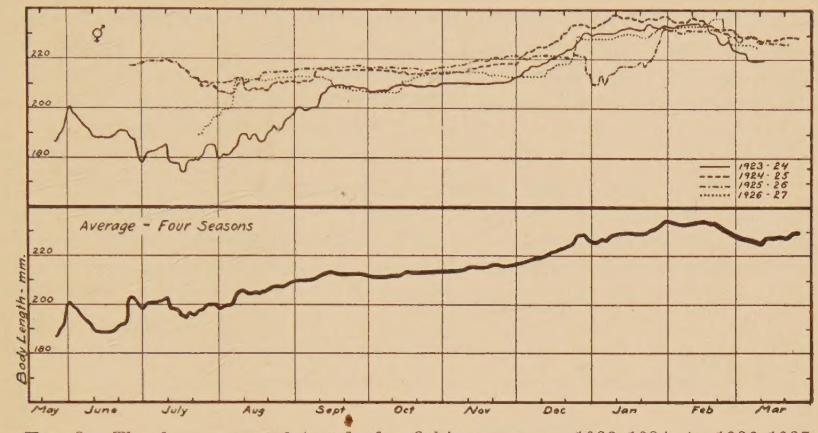

FIG. 3. The four seasonal trends for fishing seasons, 1923–1924, to 1926–1927 (above), and the average of the four seasonal trends (below).

throughout the fall months are noticeably stable as compared with the same period for the previous four seasons, and the lengths change but slightly. The transition period, between fall and winter lengths, with the exception of the 1925–1926 season, is short and gives place to a

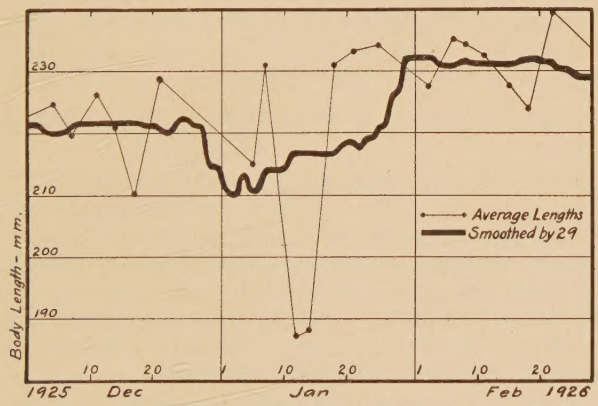

FIG. 4. A comparison of the actual average length data and the smoothed seasonal trend for the "abnormal" period, Dec. 1, 1925, to Feb. 28, 1926.

rather stable period in January and February, when the average lengths are near the maximum. After this maximum length is reached early in February the trend gradually declines to the close of the season.

The 1925–1926 season is unmistakably abnormal throughout a portion of December and January. Figure 4 shows the seasonal trend and

also the average lengths from which the trend was calculated. A strike among the fishermen was in progress the first part of December, and fishing was, therefore, irregular. Operations ceased entirely from December 23 to January 5. Fishing conditions were poor for the first half of January and the full quota of samples was not always available. Notes on the lengths of the fish for January 12 and 14 state that practically all of the fish delivered to the canneries on those days were small. On the following sample day, January 18, the average length was found to be 231 mm. The slow recovery of the trend curve is explained by the small number of sample days during the 29-day period preceding the occurrence of the two days of very low average length.

In figure 5 the trends for the first and second four-season periods are contrasted. The average of the second group of four seasonal trends differs somewhat from the first average trend. The curve for the 1923–1927 period shows a greater variation during the summer months. The sizes throughout September, October and November are more stable, as well as being 10 to 12 mm. greater than in 1919–1923. Although the transition between the fall lengths and the winter maximum lengths is much less marked in the second trend, the final maxima for the two

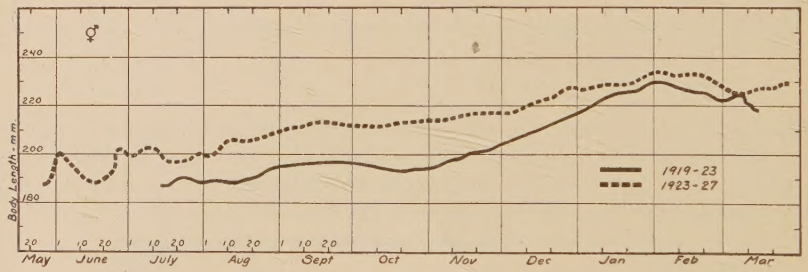

FIG. 5. A comparison of the two four-year average trends, 1919–1923, and 1923–1927.

periods are practically identical in time of occurrence and nearly equal in magnitude.

In order to show the deviation between the separate years, all trends are plotted in figure 6.[5] The heavy line, the average of the entire eight years, serves as a gauge of the deviation in average lengths of each of the eight component seasons. This graph emphasizes the wide dispersion of lengths during June, July and August, the relatively stable lengths through the fall months, and a varying transition period ending the last of January or early February followed by declining average lengths to the close of the fishing season.

Although none of the seasonal trends coincide with the eight-season average trend, this average may be considered as a "normal" year, and it may be taken as a basis of fluctuation. The extremes of the fluctuating seasonal trends may be considered the limits of the variations within which the majority of the trends of the seasons observed in the future should fall, providing conditions remain the same.

[5] The trends were obtained by smoothing the daily average lengths by a moving average of 29. As here plotted there was a slight additional smoothing by eye. At the right hand edge of this graph there has been added a scale showing the total length of fish in inches. The body length is roughly 85 per cent and the caudal fin is 15 per cent of the total length of a sardine.

However, the assumption that constant conditions will continue does not seem to be warranted. The type of gear is undergoing a marked and rapid transition in this fishery as in many others. The increasing size of launches, nets and lighters, necessarily accompanied by increased numbers in individual crews, entail a greater cruising radius and larger cannery deliveries comprised of fish caught from a wider area. These factors, combined with the increasing total cannery capacity and demand for fish, all tend to extend the fishery and to exhaust the resource the faster. In the last fifteen years which has marked sardine canning as a successful and well established industry, the only type of net used at Monterey was the lampara or "round haul." Recently, efforts have been made to introduce the purse seine. If this type of net and gear proves to be as successful in this fishery as it is at San Pedro, deviations in the character of the catch may very well be expected although not assured. Whether these factors will influence the catch qualitively as well as quantitatively is a matter of conjecture at present since the effect of altered gear in San Pedro has not been

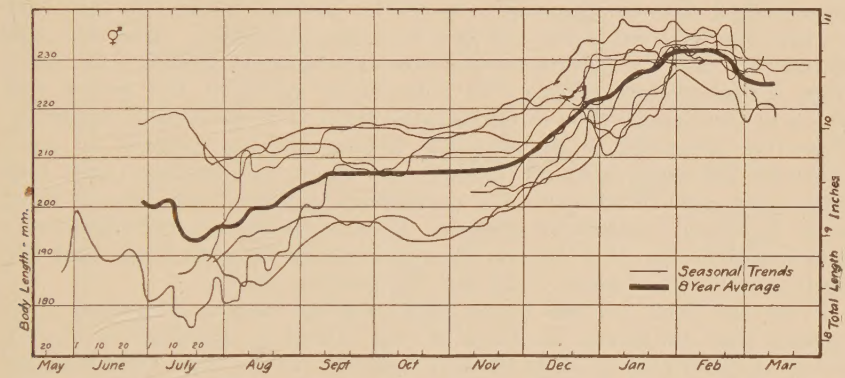

FIG. 6. The eight seasonal average length trends plotted to show deviations from the eight-season average trend.

demonstrated and the success of the purse seine type of gear in Monterey is far from established.

The foregoing factors seem to preclude any explanation of the seasonal variation in average lengths on the basis of the data at hand, and only the most conservative assumptions may be advanced. If the problem were purely a biological one, it would be much simpler, but since it is intimately related to economic conditions, any explanation or speculation as to the probable causes of the length fluctuations must necessarily be very complex. But the economic factors will have less effect on length fluctuations than upon the apparent abundance as indicated by the commercial take of sardines. It is possible, however, if it can be demonstrated that particular sizes are localized in their distribution,[6] that a decrease in demand accompanied by lessened competition among the fishermen may cause the catch of sardines to assume the aspect of the fish found in the localities most accessible to the canneries.

[6] Thompson, Will F. The California Sardine and the Study of the Available Supply. California Fish and Game Commission, Fish Bulletin No. 11, p. 19. 1926.

The change in the character of the trend throughout a season is not due to natural growth of a given year-class of sardines. Neither can it be explained on the basis of the presence of a dominant size class, although they may cause variations in the annual cycle, since various sizes react differently to specific conditions. Any argument favoring selective fishing of smaller sizes is doubtful because a particular demand for the smaller sizes is not evident. A possible explanation is that the fluctuations in length are due to the influx to the fishing grounds of schools of larger sardines. It is impossible to determine at the present time the nature of these influxes, but appearances indicate that migrations of some type are responsible for the transitions noted above. If migrations are assumed to be the primary factor in length variation, it might be of value to inspect possible types of migrations applicable to this fishery. In the species whose migrations have been most carefully worked out, such as the salmon, the eel and the smelt, the spawning instinct is probably the prime factor of the movement. For the sardine, however, the transition that occurs at Monterey between November and January can hardly be considered a spawning movement, since unpublished data on the maturity of the sardine reveal the fact that at this time the gonads are not in a maturing condition. But our data do indicate that the heterogeneous sizes appearing in March may result from a disappearance from the commercial catch of the larger fish which at this season show unmistakable signs of approaching maturity. These maturing fish may leave the fishing area to proceed to some unknown spawning ground. Food and water temperature may also cause very marked effects in the movements of fishes, but data on these latter factors are lacking at present. Were hydrological and planktonic data available for this region, the correlations between these and the sardine catch data might yield very interesting results.

From the data for the entire eight fishing seasons observed, it is evident that the trend in sizes of the Monterey sardine through a season is essentially as described by Scofield for the first four seasons. The individual years vary from the general trend of sizes slightly, but in the main, the progression is easily recognized. The lengths are small and somewhat variable during the summer months; during the fall they average several millimeters higher and are less inclined to fluctuate greatly from day to day; they gradually increase during the last of November, through December and reach a maximum in late January or early February; and in the spring the lengths are variable with the average decreasing slightly to the close of the season.

DAILY AVERAGE BODY LENGTHS OF SARDINES TAKEN AT MONTEREY DURING EIGHT SEASONS

Date	1919-20	1920-21	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27
May 23						154 90		
May 26					225 66			
June 4					177 71			
June 5					170.34			
June 6					181.37			
June 7					184.49			
June 8					181.28			
June 9			213.30					
June 10			210.52					
June 11			211.04		212.39			
June 13					228.74			
June 14					223.31			
June 15					224.01			
June 16					171.09			
June 18					176.13			
June 19					182.76			
June 20					181.74			
June 21					178.37			
June 22					177.50			
June 23					179 01			
June 25					175.32		188.38	
June 26					192.42			
July 1							231.08	
July 3							223.24	
July 7					175.30			
July 8							226.03	
July 9					166.38			
July 12				203.00	179.48			
July 13				189.61			222.10	
July 14				188.12				
July 15				172.29				
July 16					216.50		223.38	
July 17				170.60				
July 18				179 65				
July 19				173.26	184.18			
July 20				175.27			218.54	
July 21				196.15				
July 23			195.52			204.62		144.50
July 24							192.20	
July 25				205.58	146.78			
July 26			187.37	194.42			211.66	
July 27			194.13	191.69				
July 28			191 92	186.70		215.20		
July 29			197.62	188.54				
July 30			200.25		153.48		211.69	
Juiy 31				193.06				
August 1			198.00	196.51		213.22		
August 2			181.95	198.43	209.79			217.10
August 3			176.11	209.98			195.74	
August 4				208.38		217.98		
August 5			191.38	186.43				
August 6			179.74		174.18			206.69
August 7						194.60		
August 8			178.61	187.76				
August 9			184.39	184.49	214.05			203.89
August 10			184.59	191.57			211.46	
August 11			186.11	192.08		216.16		
August 12			176.65	190.68				212.46
August 13			165.37		175.29			
August 14				192.31		211.19		
August 15			178.36	186.96				
August 16			190.65	186.46	192.33			215.11
August 17			185.59	190.94				
August 18			178.88	196.83		215.01	213.67	
August 19			174.48	197.50				
August 20			175.13		206.55			213.88
August 21				193.06		215.89		
August 22			187.87	200.55			216.68	
August 23			189.33	197.20	192.69			
August 24			187.64	195.01			214.28	
August 25			195.37	200.69		175.70		
August 26			186.18	202.46	154.03			212.90
August 27			191.20				216.58	
August 28				199.14		215.66		
August 29			189.34	201.76				
August 30			193.77	201.17	185.36			212.15
August 31			199.77	200.56			213.53	
September 1			195.93	197.78		215.61		
September 2			198.04	202.02				211.93
September 3			197.43		209.92			
September 5			200.68					
September 6			196.33		213.98	216.78		209.54

DAILY AVERAGE BODY LENGTHS OF SARDINES TAKEN AT MONTEREY DURING EIGHT SEASONS—Continued

Date	1919-20	1920-21	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27
September 7			197.03					
September 8			197.91	197.30		216.46	213.42	
September 9			200.47	198.41				212.81
September 10			200.15		214.02		214.36	
September 11				199.99		217.56		
September 12			197.59	199.58				
September 13			199.60	194.91	201.14			214.39
September 14			199.24	192.28			222.19	
September 15			182.99	187.86	213.84			
September 16			186.91	193.14				217.02
September 17			183.63			216.10	216.63	
September 18				198.48				
September 19				196.12		215.02		
September 20				197.70				211.68
September 21				202.03			217.36	
September 22			196.77	199.34		215.59		
September 23			197.84	204.01				
September 24			191.42				212.96	
September 25			203.66	196.90	198.54			
September 26			207.54	194.44		217.15		
September 27			198.69	196.93	203.39			206.09
September 28			199.19	195.84			218.54	
September 29			204.01	192.72		211.46		
September 30			201.29	187.21				189.10
October 1			197.78		212.46			
October 2				198.10		215.35		
October 3			200.24	198.16				
October 4			200.54	200.02	211.35			206.77
October 5			199.41	195.86				
October 6			194.29	198.66		217.56	217.49	
October 7			196.87					209.25
October 8			197.60		210.58			
October 9				191.33		217.28	216.73	
October 10			190.66	196.18				
October 11			188.09		210.57			209.96
October 12			203.03	195.81			213.44	
October 13			200.24	198.12				
October 14			201.08	199.82				214.32
October 15			194.40		204.65			
October 16				185.89				
October 17				183.38		215.54	221.74	
October 18				192.58	209.98			211.02
October 19				192.52				
October 20			197.43	192.68		214.20	215.30	
October 21			196.80	190.83				
October 22							214.72	
October 23				184.65		216.24		
October 24				193.95				
October 25				192.59				
October 26				188.93			213.76	
October 27			190.95	189.55		208.28		
October 28			198.97					216.21
October 29			196.16		211.09		216.45	
October 30			196.26	190.38				
October 31			176.35	199.82		209.16		
November 1			190.82	199.48	212.02			213.40
November 2			185.83	197.02				
November 3				193.23		217.56		
November 4			193.70					216.68
November 5			199.16		208.64		212.53	
November 6						218.75		
November 7			202.23					
November 8		205.80	196.28	206.57	213.25			216.72
November 9		208.04	204.27	197.46			219.68	
November 10		204.03	203.00	197.48				
November 11		204.51		192.56				
November 12		198.74	201.91		209.84			
November 13		199.83		193.52			220.67	
November 14	198		198.64	199.37				
November 15	201	203.03		193.01	210.50			212.99
November 16		189.83		195.76			222.74	
November 17	195	199.98		194.96		217.76		
November 18	204	206.13		196.71				
November 19	206	207.03			209.54		219.55	
November 20	207	204.01		194.31		218.00		
November 21	209		202.45	197.15				
November 22	202	206.70	196.88	200.57				
November 23		203.54	206.21	209.22			218.39	
November 24	213	204.02		198.84		216.40		
November 25	199		185.40				220.72	

DAILY AVERAGE BODY LENGTHS OF SARDINES TAKEN AT MONTEREY DURING EIGHT SEASONS—Continued

Date	1919-20	1920-21	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27
November 26	207		196.96		210.47			
November 27				199.76				
November 28	210							
November 29	211	201.83	204.00	193.39	211.42	216.63		
November 30		209.04	199.76					213.42
December 1	203		193.94	211.40		219.38		
December 2	207	208.60		212.46				212.42
December 3	190		205.86		212.26			
December 4	211	208.98				221.54	224.94	
December 5	202		201.51					
December 6		201.62	200.03		213.33			215.03
December 7							219.68	
December 8		195.78	217.22			219.96		
December 9		198.99	210.75	215.47				
December 10	224	205.54	212.65		213.43			211.71
December 11	233	207.02					226.10	
December 12	244		216.59	212.88				
December 13		205.39			222.93			
December 14		205.39					221.46	
December 15	215	207.58						
December 16	215	204.22				238.02		
December 17	214				227.12		210.30	
December 18	208	208.86				230.84		
December 19	203		208.92					
December 20	226		221.35		230.18			
December 21		209.46	197.80	209.80			228.87	
December 22	228	210.59		207.20		231.77		
December 23	222	216.95		214.22				
December 24						224.18		
December 27	211			198.70				227.90
December 28					225.33			
December 29	218			236.39				
December 30	219	212.40						
December 31					227.63			
January 2						241.15		
January 3	216			220.87				
January 4			208.23	219.78				
January 5			218.13	229.70		239.98	215.16	
January 6				219.91				
January 7			221.93	231.69	231.90		231.03	230.80
January 8	206			223.04				
January 9	222		247.59	210.27				
January 10	226		243.82	207.94	244.46			226.54
January 11		208.55		205.32				
January 12	206	231.40					187.28	
January 13	210	216.75				229.54		229.20
January 14	216				223.05		188.46	
January 15	214							
January 16	203		228.95	232.56	234.14			
January 17	209		227.43	211.01		243.02		
January 18				226.37			231.15	
January 19	206			236.60		238.86		
January 20	219		243.63	237.84				
January 21	212		222.17				233.30	
January 22	234			240.32				
January 23	237			241.10				
January 24	226		238.22	237.96	233.44	235.60		233.44
January 25			243.28	221.26			234.48	
January 26	246		231.84	215.61		232.14		
January 27	234	231.85	234.85	243.09				231.53
January 28	234		241.25	238.77	233.24			
January 29	243			234.58				
January 30	248		219.54	229.31				
January 31	243	227.45	233.85	241.30	225.63			229.31
February 1			227.72					
February 2	237		225.24				227.73	
February 3			225.35					226.30
February 4			222.98	224.29	230.93			
February 5				240.55		239.28		
February 6	204		217.10		253.84		235.44	
February 7	225	218.90	226.75	241.82				236.79
February 8		211.98	235.34	242.78			234.55	
February 9	235	223.74						
February 10	243			207.77				241.30
February 11	233			243.12	230.11		232.88	
February 12	214			225.20				
February 13	225			230.97				
February 14	208			225.64	229.95	238.58		
February 15				215.20			227.76	
February 16	212			228.03		231.92		
February 17	205			239.44				

DAILY AVERAGE BODY LENGTHS OF SARDINES TAKEN AT MONTEREY DURING EIGHT SEASONS—Continued

Date	1919-20	1920-21	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27
February 18	203				239.98		224.73	
February 19	207			227.23		233.84		
February 20				218.01				
February 21				220.55				234.52
February 22				228.68			240.66	
February 23						242.22		
February 26				218.58		230.26		
February 27	254			247.02				
February 28	244			230.57	226.74			230.05
March 1	244			237.14				
March 2	216			226.34		223.12		
March 3	223				204.62		230.88	240.54
March 5						227.70		
March 7					227.19			
March 8	210			222.28				
March 9	217						227.80	204.98
March 10					236.16			
March 11	205						225.43	
March 12	202	213.97			204.08			
March 13	199							
March 14		217.53				220.80		
March 15		214.90					218.00	
March 16		213.92				228.56		
March 17		212.56						
March 18		213.28					236.46	
March 20						232.57		
March 22							223.94	
March 23						230.22		
March 26						233.64		
April 2		212.90						
April 7		144.25						
April 8		177.18						
April 9		193.58						

NOTE.—The average lengths for the 1919-1920 season were only calculated to the nearest millimeter. To insure greater accuracy the seasons following were computed to the second decimal place.

DIVISION OF FISH AND GAME OF CALIFORNIA
FISH BULLETINS

*No. 1. Report on Fish Conditions. 1913; 48 pp., 3 figs. Contains:

a. The Abalone Industry in California. By Charles Lincoln Edwards.

b. The Towing of Salmon and Steelhead Fry from Sacramento to the Sea in a "Live Car." By N. B. Scofield.

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e. Investigation of the Life History of the Edible Crab (*Cancer magister*). By F. W. Weymouth.

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*No. 2. The Scientific Investigation of Marine Fisheries as Related to the Work of the Fish and Game Commission in Southern California. By Will F. Thompson. 1919; 27 pp., 4 figs.

*No. 3. The Spawning of the Grunion (*Leuresthes tenuis*). By Will F. Thompson, assisted by Julia Bell Thompson. July 15, 1919; 29 pp., 9 figs.

No. 4. The Edible Clams, Mussels and Scallops of California. By Frank W. Weymouth. Jan. 10, 1921; 74 pp., 19 pls., 26 figs.

*No. 5. A Key to the Families of Marine Fishes of the West Coast. By Edwin C. Starks. March 3, 1921; 16 pp., 4 figs.

*No. 6. A History of California Shore Whaling. By Edwin C. Starks. October, 1922; 38 pp., 22 figs.

*No. 7. The Life History and Growth of the Pismo Clam. By Frank W. Weymouth. 1923; 120 pp., 15 figs., 18 graphs.

*No. 8. Racial and Season Variation in the Pacific Herring, California Sardine and California Anchovy. By Carl L. Hubbs. February, 1925; 23 pp., 4 pls.

*No. 9. Preliminary Investigation of the Purse Seine Industry of Southern California. By Tage Skogsberg. 95 pp., 23 figs.

*No. 10. The Life History of *Leuresthes tenuis*, an Atherine Fish with Tide-controlled Spawning Habits. By Frances N. Clark. October, 1925; 51 pp., 6 graphs, 7 pls.

No. 11. The California Sardine. By the Staff of the California State Fisheries Laboratory. 1926; 221 pp., 74 figs.

Thompson, Will F. The California Sardine and the Study of the Available Supply.

Sette, Oscar Elton. Sampling the California Sardine: A study of the adequacy of various systems at Monterey.

Higgins, Elmer H. A Study of Fluctuations in the Sardine Fishery at San Pedro.

Scofield, W. L. The Sardine at Monterey: Dominant size classes and their progression, 1919–1923.

Thompson, Will F. Errors in the Method of Sampling Used in the Study of the California Sardine.

No. 12. The Weight-Length Relationship of the California Sardine (*Sardina caerulea*) at San Pedro. By Frances N. Clark. 1928.

No. 13. Seasonal Average Length Trends at Monterey of the California Sardine (*Sardina caerulea*). By Carroll B. Andrews. 1928.

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